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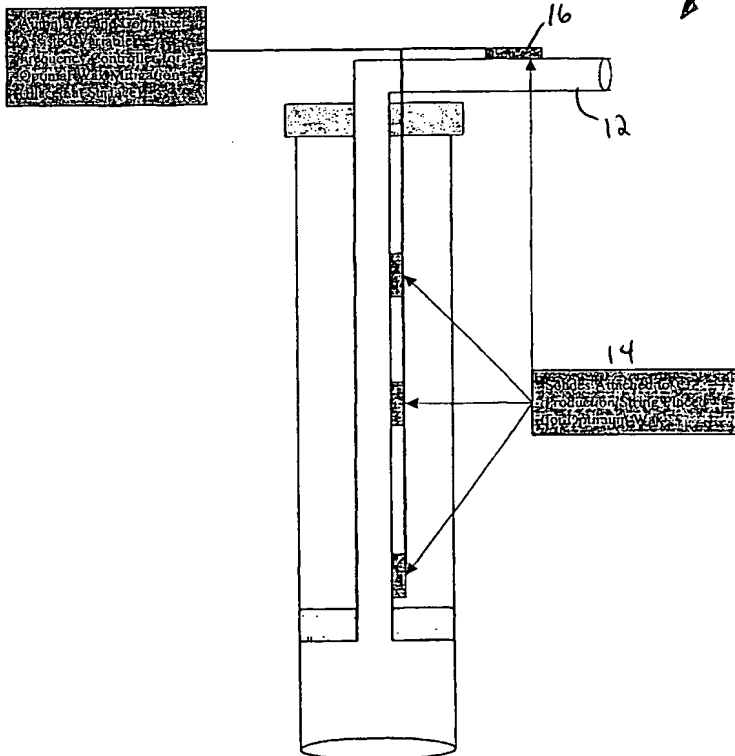
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[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR THE MITIGATION OF PARAFFIN WAX DEPOSITION FROM CRUDE OIL BY USING ULTRASONIC WAVES

Typical Setup on Production String



(57) Abstract: A method for mitigating the deposition of wax on production tubing walls. The method comprises positioning at least one ultrasonic frequency generating device adjacent the production tubing walls and producing at least one ultrasonic frequency thereby disintegrating the wax and inhibiting the wax from attaching to the production tubing walls. A system for mitigating the deposition of wax on production tubing walls is also provided.

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SYSTEM AND METHOD FOR THE MITIGATION OF PARAFFIN WAX
DEPOSITION FROM CRUDE OIL BY USING ULTRASONIC WAVES

The present application is a continuation of pending provisional patent application Serial No. 60/410,472, filed on September 13, 2002, entitled "System and Method for the Mitigation of Paraffin Wax Deposition From Crude Oil By Using Ultrasonic Waves".

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to system and method for the mitigation of paraffin wax deposition from crude oil and, more particularly, the invention relates to a system and method for the mitigation of paraffin wax deposition from crude oil by using ultrasonic waves.

2. Description of the Prior Art

Wax deposition from crude oil is an enormously expensive problem for oil producers around the world. In the field, the production tubing is often plugged by paraffin wax which deposits on the walls of the production tubing and surface flow equipment. The deposition of the paraffin leads to a fall in the production rates of the oil from that well.

The deposition of the paraffin waxes from the reservoir fluid occurs when the temperature and pressure move below the cloud point of the fluid. The paraffin deposits start off as a thin film and slowly deposits in the form of crystalline solids, which collects on the interior of the tubing and flow-lines and slowly chokes off the production.

Basically, paraffin deposits are carbonaceous material, which is not soluble or dispersible by the crude oil under the prevailing conditions. Paraffins are composed primarily of alkanes with formulas $C_{18}H_{38}$ to $C_{70}H_{142}$. These are straight chained and branch chained compounds, and are generally inert and resistant to attack by acids, bases, and oxidizing agents. Previous research has shown that n-paraffins are more responsible for this problem. The formation of the deposit depends on the cloud point, an available surface and or loss of gas or light ends due to a drop in pressure.

1 The precipitation is not uniform; it has peaks at certain points in the tubing and less
2 deposition at other places.

3 The cloud point temperature is the key factor controlling the paraffin wax
4 deposition. Paraffinic hydrocarbon liquids form a paraffin or wax solid phase when
5 the temperature falls below the cloud point, or Wax Appearance Temperature (WAT),
6 of the oil. As the oil flows up the well-bore, its pressure drops causing solution gas to
7 liberate. This solution gas which is liberated acts to some degree as a solvent for
8 waxes. Therefore, the loss of gas increases the cloud point temperature causing more
9 precipitation and also makes the oil more viscous.

10 Also, as the oil moves upward, it cools since the ground temperature is less
11 than the reservoir temperature. There is a temperature gradient at the wall and when
12 the oil temperature reaches the cloud point the precipitation starts. This precipitation
13 occurs even if the bulk oil temperature is more than the cloud point temperature,
14 because it is the temperature of the oil at the wall, which plays the most important role
15 in the precipitation of wax. The wax deposition problem is more prevalent in low
16 flow rate wells because of the high residence time of oil in the well-bore. The
17 increased flow time leads to more heat loss, which results in lowering of oil
18 temperature and leads to wax precipitation and deposition. Well-bore studies have
19 shown that the temperature profile in the well-bore is a strong function of the flow-
20 rate. The paraffin wax problem is an example of fluid/solid equilibrium, which is
21 described as a solution of higher molecular weight hydrocarbons in low molecular
22 weight hydrocarbons which act as solvents.

23

24 SUMMARY

25 The present invention is a method for mitigating the deposition of wax on
26 production tubing walls. The method comprises positioning at least one ultrasonic
27 frequency generating device adjacent the production tubing walls and producing at
28 least one ultrasonic frequency thereby disintegrating the wax and inhibiting the wax
29 from attaching to the production tubing walls.

30 In addition, the present invention includes a system for mitigating the
31 deposition of wax on production tubing walls. The system comprises at least one
32 ultrasonic frequency generating device adjacent the production tubing walls and at
33 least one ultrasonic frequency generated by the generating device thereby

1 disintegrating the wax and inhibiting the wax from attaching to the production tubing
2 walls.

3

4 BRIEF DESCRIPTION OF THE DRAWINGS

5 FIG. 1 is a schematic drawing illustrating the system and method for
6 mitigation of paraffin wax deposition from crude oil using ultrasonic waves,
7 constructed in accordance with the present invention;

8 FIG. 2 is a schematic drawing illustrating the system and method for
9 mitigation of paraffin wax deposition from crude oil using ultrasonic waves,
10 constructed in accordance with the present invention, with the tube in the horizontal
11 orientation;

12 FIG. 3 is a schematic drawing illustrating the system and method for
13 mitigation of paraffin wax deposition from crude oil using ultrasonic waves,
14 constructed in accordance with the present invention, with the tube in the vertical
15 orientation; and

16 FIG. 4 is a schematic drawing illustrating an experimental setup of the system
17 and method for mitigation of paraffin wax deposition from crude oil using ultrasonic
18 waves, constructed in accordance with the present invention, with an ultrasonic water
19 bath connected to a water cooler pump combination used to circulate water at a fixed
20 temperature.

21

22 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

23 As illustrated in FIG. 1, the present invention is a system and method,
24 indicated generally at 10, for mitigating the deposition of wax on production tubing 12
25 accumulated from crude oil during production by the use of ultrasonic waves. The
26 system and method of the present invention uses ultrasonic waves to disintegrate the
27 wax and inhibit the wax from attaching to the walls.

28 The ultrasonic waves or frequencies are generated by at least one device or
29 sonde 14 attached to the outside of the production tubing 12 at strategic locations
30 along its length. While three particular frequencies have been identified as the
31 optimal frequencies of operation, these are only a guide for selection of the desirable
32 frequencies of operation. In a preferred embodiment, the high frequency is
33 approximately five hundred (500) KHz and the low frequency is about ten (10) KHz.

1 The first frequency is the characteristic frequency of the production tubing,
2 designated optimal frequency one (OF1). Using the first frequency, the ultrasonic
3 waves set the production tubing 12 vibrating thereby inhibiting the wax from
4 depositing on the wall. The second frequency (optimal frequency two (OF2)) is the
5 frequency that breaks the wax up into smaller particles by breaking the bonds which
6 cause the wax molecules to adhere together. The third frequency (optimal frequency
7 three (OF3)) actually breaks the bonds of the wax molecules so that the long chained
8 alkanes are broken down into smaller molecules. These smaller molecules will be
9 more soluble in the oil and so will not precipitate out as wax. Consequently the
10 ultrasonic wave generator 14 will be broadcasting at all or any of the three frequencies
11 depending on which of the frequencies are not having the desired effect.

12 In practice, however, these three frequencies would only be a guide for
13 selection of the desirable frequencies of operation. The present invention includes a
14 variable frequency device 16 for determining the optimal frequencies in the range
15 around the three theoretical optimal frequencies. The ultrasonic broadcast device 14
16 generates all three frequencies, once they have been identified by the variable
17 frequency device 16.

18 The three frequencies would have three separate effects. As briefly described
19 above, the OF1 sets the production tubing walls 12 vibrating and hence, inhibits wax
20 molecules from depositing on the walls. Instead, the wax molecules remain entrained
21 in the flowing oil and are carried away. The OF2 inhibits the precipitated wax
22 molecules from adhering together and from adhering to the walls. The OF3 breaks the
23 unprecipitated long chain wax molecules into smaller molecules and makes the wax
24 molecules more soluble in the oil thereby lowering the cloud point temperature and
25 allowing the molecules to remain in solution. The combination of these three effects
26 greatly reduces the wax deposition so that it is more manageable and removal is
27 required far less frequently.

28 As illustrated in FIGS. 2 and 3, a paraffin deposition flow system 20 has been
29 constructed to simulate the deposition of paraffin in the wells. The flow system 20
30 consists of two concentric tubes with a facility to measure the pressure drop between
31 the ends of the inner tube, called the test section. The crude oil used to conduct the
32 experiments is stored in a reservoir having a capacity of ten gallons. The crude can be
33 pumped into the test section and back into the reservoir. The flow rate is adjusted

1 using a flow meter and a bypass valve. An inclined manometer is used to measure the
2 pressure drop across the section. The pressure drop is used to determine the pipe
3 diameter and hence the thickness of the wax deposition. The manometer was inclined
4 at an angle of thirty-five (35°) degrees to the horizontal and the manometric fluid is
5 water. A facility to monitor the temperature in the test section and in the reservoir is
6 also provided. A blower was required to keep the pump from over heating as the
7 experiments are run for long periods. A water bath attached to a refrigeration unit is
8 used to provide cooling for the walls of the inner tube.

9 Water is pumped into the outer annulus and then back into the water bath
10 maintaining the walls of the test section at the required temperature throughout the
11 experiment. At the start of each experiment, the manometer is checked to ensure zero
12 reading and the flow rate adjusted using pump speed and a bypass valve. Manometer
13 readings are noted at regular intervals until the end of the experiment. At the end of
14 experiment, all the pumps and coolers are switched off and test section is disassembled.
15 Paraffin that is deposited in the test section is removed using scrapers and the amount
16 of paraffin measured using a measuring jar. The ultrasonic frequency generating
17 equipment is attached to the outside of the tube carrying the flowing oil.

18 The static experimental setup to study the effect of ultrasonic waves on wax
19 deposition is shown in Fig. 4. It consists of an ultrasonic water bath that was
20 connected to a water cooler pump combination that was used to circulate the water at
21 some fixed temperature throughout the duration of the experiment.

22 The foregoing exemplary descriptions and the illustrative preferred
23 embodiments of the present invention have been explained in the drawings and
24 described in detail, with varying modifications and alternative embodiments being
25 taught. While the invention has been so shown, described and illustrated, it should be
26 understood by those skilled in the art that equivalent changes in form and detail may
27 be made therein without departing from the true spirit and scope of the invention, and
28 that the scope of the present invention is to be limited only to the claims except as
29 precluded by the prior art. Moreover, the invention as disclosed herein, may be
30 suitably practiced in the absence of the specific elements which are disclosed herein.

1 CLAIMS

2

3 What is claimed is:

4

5 1. A method for mitigating the deposition of wax on production tubing walls, the
6 method comprising:

7 positioning at least one ultrasonic frequency generating device adjacent the
8 production tubing walls; and

9 producing at least one ultrasonic frequency thereby disintegrating the wax and
10 inhibiting the wax from attaching to the production tubing walls.

11

12 2. The method of claim 1 and further comprising:

13 producing three predetermined frequencies, the frequencies being a first
14 frequency, a second frequency, and a third frequency.

15

16 3. The method of claim 1 wherein the three frequencies range between
17 approximately ten (10) KHz and approximately five hundred (500) KHz.

18

19 4. The method of claim 2 and further comprising:

20 producing the first frequency;

21 vibrating the production tubing; and

22 inhibiting the wax from depositing on the production tubing walls.

23

24 5. The method of claim 2 and further comprising:

25 producing the second frequency; and

26 breaking the bonds adhering the wax molecules together thereby disintegrating
27 the wax into particles.

28

29 6. The method of claim 2 and further comprising:

30 producing the third frequency;

31 reducing the long chained alkanes of the wax molecules thereby reducing the
32 wax into smaller molecules.

33

- 1 7. The method of claim 2 and further comprising:
2 generating all three predetermined frequencies simultaneously.
3
- 4 8. The method of claim 1 and further comprising:
5 determining the optimal frequencies with a variable frequency device.
6
- 7 9. A system for mitigating the deposition of wax on production tubing walls, the
8 system comprising:
9 at least one ultrasonic frequency generating device adjacent the production
10 tubing walls; and
11 at least one ultrasonic frequency generated by the generating device thereby
12 disintegrating the wax and inhibiting the wax from attaching to the
13 production tubing walls.
14
- 15 10. The system of claim 9 wherein three predetermined frequencies are generated.
16
- 17 11. The system of claim 9 wherein the three frequencies range between
18 approximately ten (10) KHz and approximately five hundred (500) KHz.
19
- 20 12. The system of claim 10 wherein the first frequency is approximately equal to
21 the characteristic frequency of the production tubing thereby vibrating the production
22 tubing and inhibiting the wax from depositing on the production tubing walls.
23
- 24 13. The system of claim 10 wherein the second frequency has a frequency
25 sufficient to disintegrate the wax into particles by breaking the bonds which cause the
26 wax molecules to adhere together.
27
- 28 14. The system of claim 10 wherein the third frequency has a frequency sufficient
29 to break the bonds of the wax molecules so that the long chained alkanes are broken
30 down into smaller molecules.
31
- 32 15. The system of claim 10 and further comprising:
33 generating all three predetermined frequencies simultaneously.

1

2 16. The system of claim 9 and further comprising:

3 a variable frequency device for determining the optimum frequencies.

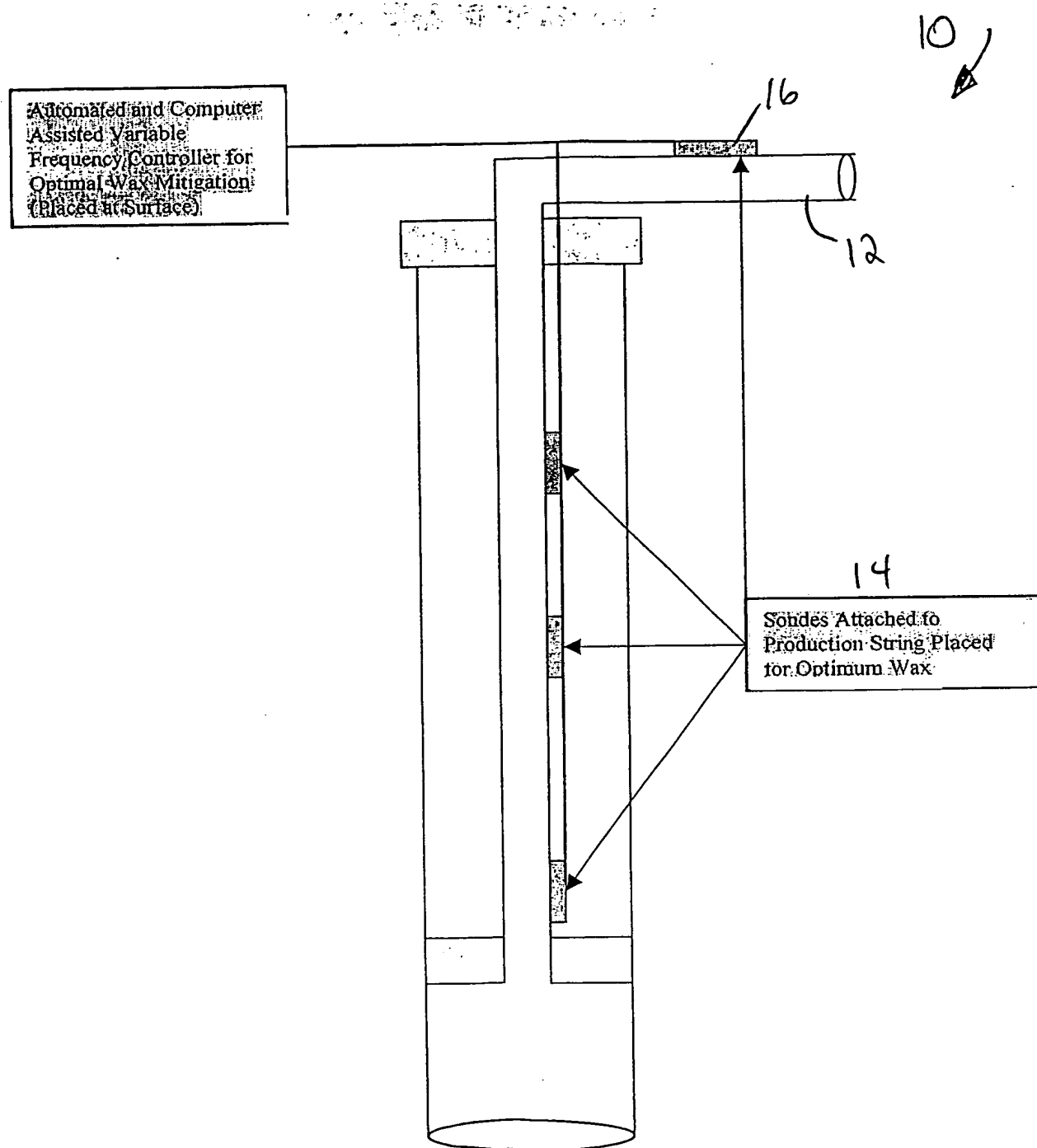
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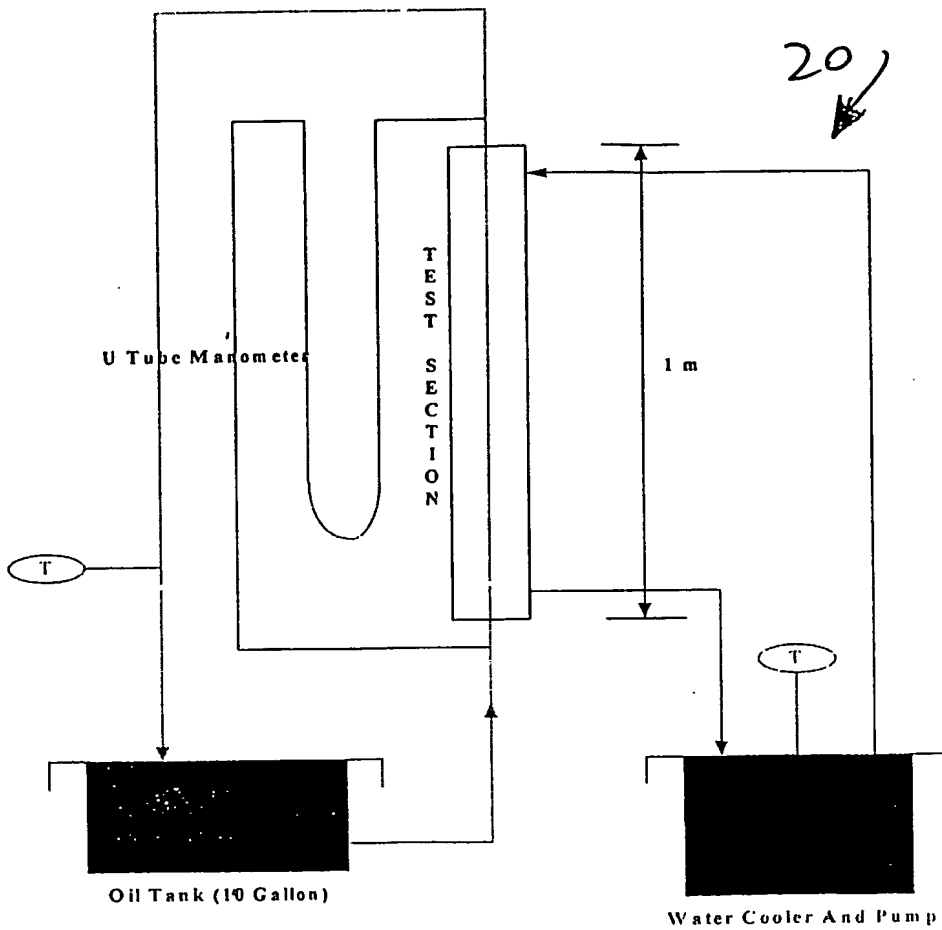
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Fig. 1 Typical Setup on Production String



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Fig. 2 Tube in the horizontal orientation



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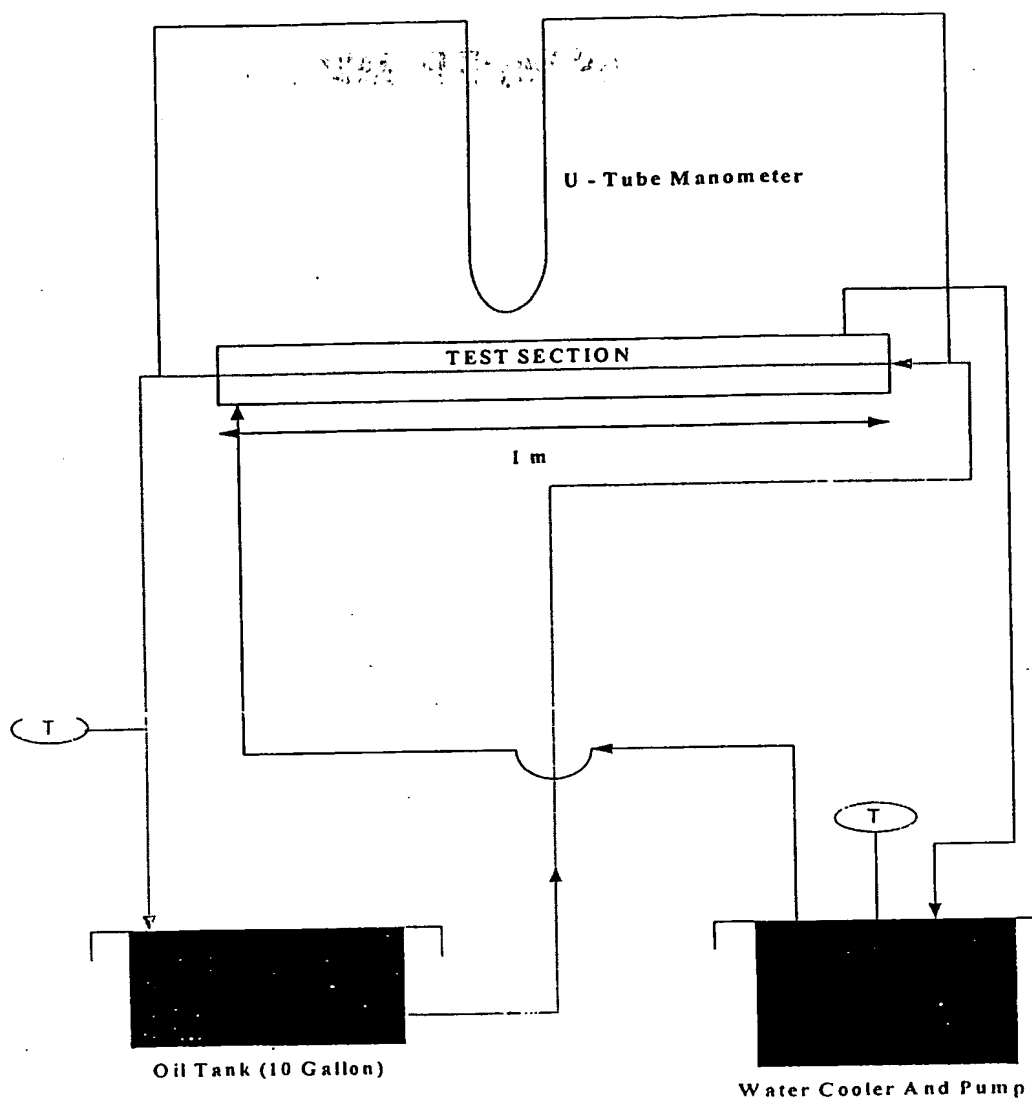


Fig. 3 Tube in the vertical orientation

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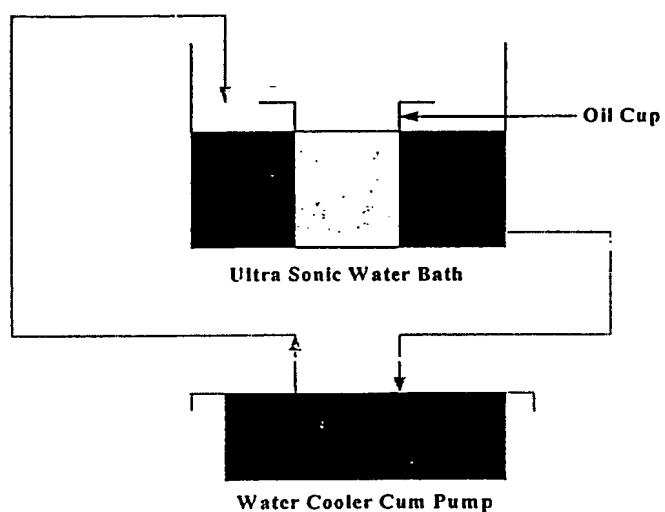


Fig. 4 Setup for the experiments using ultrasonic waves

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/28834

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : E21B 37/08

US CL : 166/304

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 166/304,310,902

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,958,683 A (ALFORD et al) 25 September 1990 (25/09/90), see entire document.	1 and 9

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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INTERNATIONAL SEARCH REPORT

PCT/US03/28834

Continuation of B. FIELDS SEARCHED Item 3:

East

search terms: wax or paraffin and ultrasonic